THE AUSTRALIAN BUILT ENVIRONMENT: CURRENT CHALLENGES AND INNOVATIVE RESPONSES

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Introduction

The exploratory research presented in this discussion paper was undertaken as input to a major research grant application for the Australian Research Council. The research examines the contribution of the Australian built environment to meet social and environmental needs. The paper examines the following research questions:

1. What are the main challenges facing the Australian built environment?

2. What types of building innovations might address those challenges?

The research questions were addressed through desk-top research, involving an international review of (1) relevant academic literature in top-tier construction management and general management journals, and (2) high profile industry reports published internationally. Future research will involve assessing the diffusion of the identified building innovations and gauging their impact on social and environmental goals.

Background

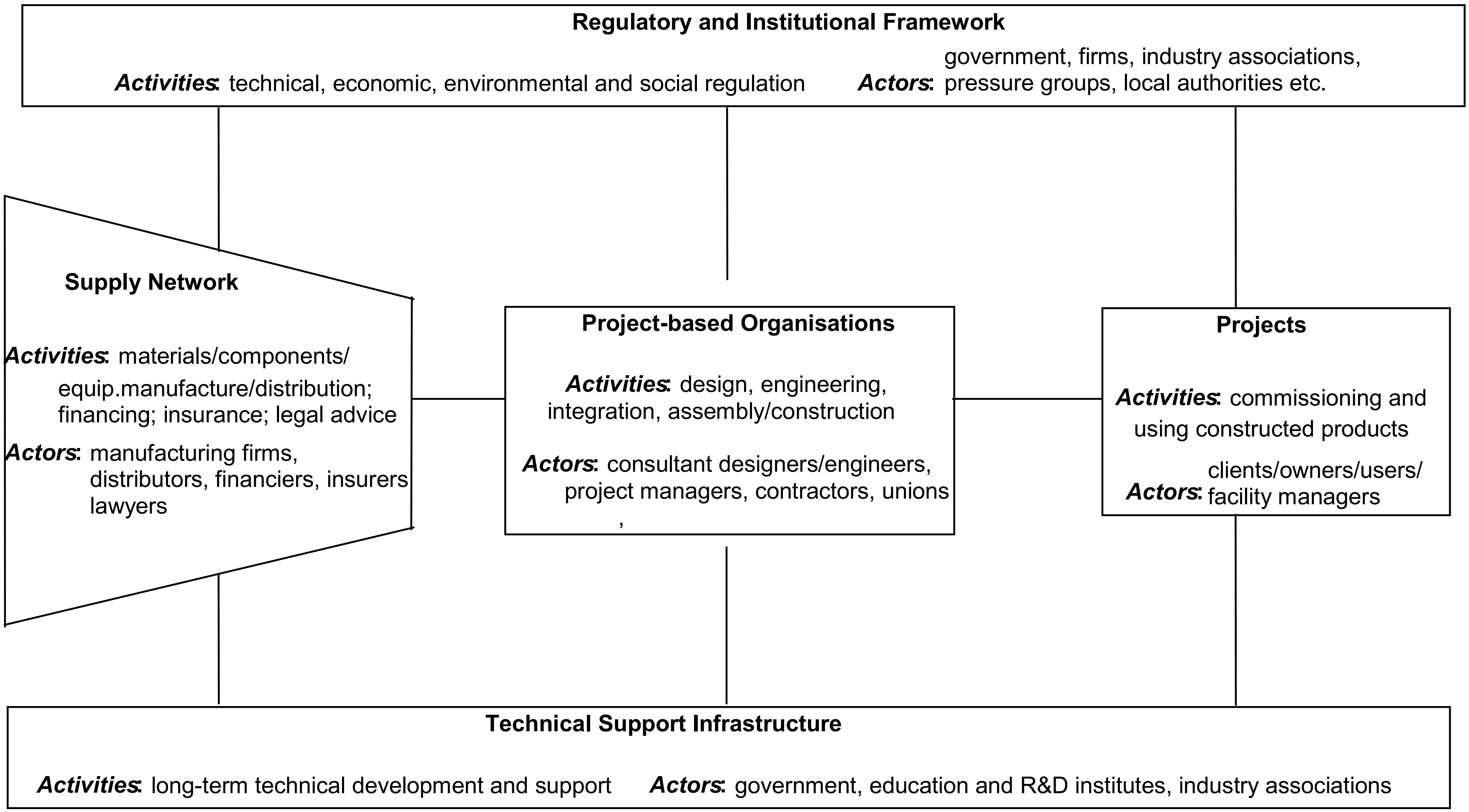
Australia's built environment is created and maintained by the construction industry. The statistical agencies of most developed countries define the industry quite narrowly to comprise only contractors. This definition gives a contribution to GDP of around 5-7%. However, using a 'product system' definition of the industry roughly doubles its GDP contribution to between 10-14% (Manseau, 2004, Ruddock and Wharton, 2004, DISR, 1999, Marceau et al., 1999, Argy, 2008). The expanded definition includes not only contractors, but also design consultants, building product manufacturers and facility managers. Viewing the construction industry as a product system provides a more comprehensive picture of the activities and actors that sustain Australia's built environment.

The Construction Product System is shown in Chart 1 which reveals the relationships between key activities and actors in the system. The regulatory and institutional framework shapes, and is shaped by, the supply network, project-based firms and projects themselves, with the technical support infrastructure playing a similar role. Many of the actors shown here are well known to industry analysts; actors like consultants, contractors, clients and distributors. Others are less often considered when the performance of the construction industry is analysed. These actors include financiers and insurers, for instance, who have an impact on the financial feasibility of innovations. If long-term positive environmental ramifications are not considered by these actors in return-on-investment calculations, then innovation may be constrained below the socially optimal level.

Other actors not always considered in industry analyses include educational institutions, R&D institutes and unions. Education institutions need to provide up-to-date training opportunities to match the demands of emerging innovations. R&D institutes, on the other hand, play a direct role in developing, co-developing, and/or testing innovations. The role of unions can be more problematic, with the multitude of unions within the industry potentially creating rigid labour boundaries that impede innovation implementation. Australia's federal political system exacerbates these problems through inconsistency and duplication, and is an extra challenge for the entire product system compared to a unified political structure.

Chart 1 usefully collects the actors and activities within the product system and provides background to our investigation of current challenges facing the system.

Chart 1: Activities and Actors in the Construction Product System



Source: (Gann and Salter, 2000)

Methods

Current challenges facing the above product system in Australia were assessed based on desk-top research comprising an international literature review. A panel of two researchers assessed the most highly cited industry and academic sources that focus on the built environment. Based on analysis of relevant articles, the two researchers independently created a list of key themes. The results were compared and the theme categories were rationalised manually. The challenges and innovations discussed in this paper comprise a rationalisation of those themes that were commonly listed by both researchers.. The results are not exhaustive, but they do cover the main innovations offering environmental and productivity benefits in response to the main challenges identified.

The following types of sources were consulted in the literature review: construction management journals: e.g. Construction Management and Economics; general management journals: e.g. Research Policy; OECD reports: e.g. Environment Directorate; Industry surveys: e.g. Price Waterhouse Coopers (PWC); and government reports from Australia and the UK: e.g. Cole Royal Commission. The focus on the UK to inform Australian research is justified by the similar challenges facing the construction industry in both countries.

Current Challenges

Australia and the UK have undertaken numerous studies detailing the problems facing the industry (Gyles, 1992, CIDA, 1995, NatBACC, 1999, PWC, 2002, Cole, 2003, Fairclough, 2002, Egan, 1998, Latham, 1994, Strategic Forum, 2002). The problems common to both countries include fragmented production, lowest-cost tender selection, prescriptive specifications, inequitable risk distribution, and adversarial relationships. These and related issues have negatively impacted innovation rates, so that the incidence of innovation in the construction industry internationally compares poorly with other sectors, such as manufacturing (Reichstein et al., 2005).[1] In the Australian context, research by PricewaterhouseCoopers (PWC) has found that the construction industry is slow to innovate, compared to other industries *and* other countries (PWC, 2002).

Persistently poor performance is also reflected in the fact that construction clients globally remain dissatisfied with typical project outcomes (Strategic Forum, 2002, Boyd and Chinyio, 2006). The answer to the industry's continuing problems is said to lie in building a stronger innovation culture to improve the rate and quality of innovation across the construction system (Hartmann, 2006b, Hartmann, 2006a). The industry appears to be moving in this direction, with an authoritative new book in Australia claiming that 'there has been a significant improvement in the level and quality of communication and collaboration between stakeholders which is yielding initiatives that promise to lift future performance' (Newton et al., 2009).

Such improvement was kick-started by the Action Agenda program in Australia, and the Construction Excellence program in the UK. In Australia, the Building and Construction Industries Action Agenda led to the formation of the Cooperative Research Centre for Construction Innovation, which has created a more positive innovation culture within the industry, through initiatives such as the BRITE Project (STEM, 2006). These beginnings need to be fortified over the long-term through ongoing government investment to correct continuing market failures such as uncertainty, asymmetric information, market power and spillover benefits/costs. These market imperfections result in innovation rates that are less than socially optimal. Despite some positive trends, government investment is particularly important at the present time because the industry currently faces a new wave of challenges, as detailed below:

[1] By broadly interpreting the construction industry as a system, Reichstein et al. (2005) were able to ensure a fair comparison, as recommended by Winch (2003).

1. Like many industrialised countries, Australia is currently grappling with the problem of a rapidly decaying built environment (Lewis, 2009). Substantial infrastructure investment is required to alleviate this situation and innovation in products and processes helps ensure maximum value-for-money.
2. Until the Global Financial Crisis hit Australia in 2008, the country had experienced the most sustained period of rapid economic growth ever witnessed (CEDA, 2005). This experience strained existing infrastructure (see Box 1) and underscored our resource constraints that hamper effective planning and construction of the built environment. Innovation helps manage the risks associated with resource shortages by delivering new ways of working smarter.
3. Globally, policy attention directed toward climate change and environmental sustainability by scientists, governments, industrialists and community groups has never been greater (OECD Environment Directorate, 2009). This creates challenges for reducing the impact of constructing and maintaining the built environment on the earth, requiring innovative solutions.
4. The increasing frequency of weather-driven disasters, such as floods and fires, creates the need for new ways of building that can accommodate weather extremes (Lindell and Prater, 2003). This need was underscored by the January 2011 floods in Australia.

Chart 2: Focus on Infrastructure

A crisis of inadequate Australian infrastructure in transport, energy, water, communication, health and education has emerged over the past 20 years (CEDA, 2005, Argy, 2008, DISR, 1999). A recent CEDA report identifies a 'deep-seated infrastructure delivery problem' stemming from declining real infrastructure investment nationally since the 1980s (CEDA, 2005). Despite other time series data showing a more positive picture (Coombs and Roberts, 2007, Marceau et al., 1999, Ruddock and Wharton, 2004), key commentators agree that Australia's infrastructure stock is rapidly aging, compromising the economy's productive capacity (BCA, 2007, Coombs and Roberts, 2007, CEDA, 2005). Engineers Australia claims that over the past 10-20 years, 'there has been significant underinvestment in new infrastructure and that there has been insufficient attention to maintaining and renewing existing infrastructure' (Engineers Australia, 2008, CIDA, 1995).

Recent changes of government at federal and state levels have seen policy shifts to a much more proactive stance on infrastructure investment, with massive programs recently being launched nationally, and across the states. Indeed, Australia recently experienced the early stages of an infrastructure boom (Potter, 2008), that has persisted in the face of the GFC shock due to extensive mining activity. The scale of expected infrastructure investment over the next 20 years is unprecedented in Australia's history, resulting in significant challenges to efficient and effective delivery. Major capacity and cost challenges driven by rapidly escalating mining and construction activity have been experienced, and are expected to continue in the long-term despite the current turbulence in world financial markets. Although we face uncertain times, it is clear that in the long-run, Australia's international competitiveness will require a significant boost to infrastructure spending. Against this backdrop, the effectiveness and efficiency of infrastructure projects is particularly critical. This is where innovation is critical – as a driver of improved project outcomes.

Innovative Responses

Given these challenges, innovative methods of constructing the Australian built environment have never been more urgently needed. The main underlying area in which innovation is required is in resource use. The idea that we have abundant natural resources, which once dominated economic thinking, is no longer useful. Acknowledgement of the finite limits to resource availability helps underscore the areas within the built environment where innovation will add maximum value. This is in relation to environmental sustainability. The literature review revealed that promising innovations are currently developing in two broad areas related to social and environmental sustainability: (1) design and planning innovations; and (2) material, equipment and machinery innovations. Chart 3 shows the sub-categories showing promise within these two areas.

Chart 3: Selected Innovations, Australian Sustainable Built Environment Industry, 2009

Sustainable Built Environment Innovation

DESIGN AND PLANNING INNOVATIONS

- **Virtual building design and information modelling**
  - 3D modelling
  - Construction Programming (4D)
  - Baseline quantities and costs (5D)
  - Direct fabrication
  - Asset Management
- **Off-site manufacture**
  - Just-in-time
  - Lean production
  - Concurrent engineering and design
  - IT-enabled planning
  - Time- and space-based scheduling
- **Green urbanism**
  - Sustainable communities
  - SlimCity
  - Urban informatics

MATERIAL, EQUIPMENT AND MACHINERY INNOVATIONS

- **Passive building technologies**
  - Passive lighting systems
  - Advanced insulation technology
  - Spectrally-sensitive glazing
  - Dynamic façade systems
  - Passive efficiency modelling
- **Sustainable products**
  - Energy Innovations
  - Material Innovations
- **Extreme weather-proofing technology**
  - Fire-retardant construction materials
  - Flooding and cyclone resistance
  - Disaster mitigation modelling
- **Control and monitoring systems**
  - Building management systems
  - Automated project performance control
  - Machine guidance technology

These innovations all have the potential to contribute in a significant way to meeting the four key challenges discussed above, by improving the efficiency and effectiveness of resource use. The expected impact of these innovations is described after taking into account the various dimensions of innovation, which are summarised in Chart 4. Our analysis commences with a definition of the term 'innovation'. Putting aside the plethora of definitions offered by individual authors from various industry and discipline backgrounds, the most authoritative definition is that provided by the OECD (2005) where innovation is considered to be a significant change in products, processes, work organisation or marketing methods. The changes may be new to the firm, sector or world. Chart 4 provides more detail concerning the OECD definition of innovation, and includes other authoritative views of innovation.

Chart 4: Key Innovation Typologies

Author(s)	Type of innovation is based on …	Categories of innovation
OECD (2005)	Output class	**Product** – good or service **Process** – production or delivery method **Marketing** – packaging, placement, pricing **Organisational** – internal business practices The intention is that these OECD categories are mutually exclusive and that they cover all possible types of innovation output by firms. Product and process innovation tends to be technical/ technological in character.
OECD (2005)	Degree of novelty	**New to the firm** – lowest degree of novelty – innovation adopted from within the industry **New to the industry** – innovation adopted from another industry **New to the world** – highest degree of novelty – previously unseen innovation – likely to be patented if technological in nature
(Harty, 2005)	Implementer's control	**Bounded** – innovation implementation can be contained within a single sphere of influence **Unbounded** – innovation implementation takes place in more contested domains
(Gopalakrishnan and Bierly, 2001)	Knowledge characteristics	**Tacit/Explicit** – codifiability, teachability, observability, articulateness **Systemic/Autonomous** – extent to which knowledge components are linked with other components **Complex/Simple** – sophistication of knowledge [last two dimensions reflect Slaughter 2000]
(Slaughter, 2000)	Change in knowledge and change in system linkages (System linkages first addressed by Teece 1986).	**Incremental** – small change in knowledge and small system impact **Architectural** – small change in knowledge and large system impact **Modular** – large change in knowledge and small system impact **System** – large change in knowledge from a combined set of innovations and large system impact **Radical** – large change in knowledge and new system
(Mitropoulos and Tatum, 1999)	Decision making (Similar to Winch 1998).	**Strategic** – continuous monitoring of ideas, thorough evaluation of options, top management participation, seeking to maximise benefits [proactive innovation] **Project** – solution-driven innovation, limited evaluation of available options, seeking to minimise consequences of failure [reactive innovation]
(Winch, 1998)	Source of idea	**Top down** – new idea adopted by firm's managers and implemented on projects [proactive innovation] **Bottom up** – new idea is the result of problem-solving on construction-sites, which may be later learned by the firm [reactive innovation]
(Rothwell, 1994)/(Powell, 1991)	Process	**Linear/Firm-based** – innovation process managed by a single firm **Interactive/Networked** – innovation process shared between firms
(Teece, 1986)	System linkages	**Autonomous** – little system impact **Systemic** – large system impact

Source: (Manley, 2008a)

The literature reveals increasing sophistication in the characterisation of different types of innovation, from simple distinctions between product and process innovation to more detailed categories along an expanding set of dimensions. The different views shown in Chart 4 help us to understand how the innovations in Chart 3 might address challenges facing the Australian built environment.

Design and Planning Innovations

These innovations all improve integration of the supply chain. Implementation is difficult due to their unbounded, systemic, networked and often tacit nature. These innovations embody the three output classes proposed by the OECD: product, process and organisational. This complex profile both hampers diffusion, and underpins the significant system wide benefits expected across the actors and activities in Chart 1. The rate of adoption of these innovations is rapidly increasing in Australia and the associated efficiency improvements are already improving resource use and environmental outcomes. Maximisation of benefits will depend on the strength of relationships between project-based organisations and the other critical system participants.

Material, Equipment and Machinery Innovations

These innovations can all be classed as product outputs. They are more autonomous in nature, compared to the design and planning innovations. Material, equipment and machinery innovations tend to be bounded, linear and explicit. This means that diffusion tends to be rapid. The impact of these innovations on the challenges faced by the Australian built environment tends to be incremental, although improvements in resource use and environmental sustainability are substantial over time. In terms of the actors and activities impacted by these innovations, diffusion tends to be driven by the supply network shown in Chart 1, with the support of technical and regulatory actors. Ultimate adoption depends on relationships with project based organisations and their clients.

Conclusions

The innovations listed in Chart 3 all have the potential to contribute in a significant way to meeting the four key challenges raised earlier, by (1) addressing the need for state-of-the-art infrastructure; (2) planning for resource shortages, including constrained supplies of skilled labour, energy and water; (3) reducing our contribution to climate change; and (4) developing building innovations that resist fire and flood.

The construction industry needs to reinvent itself in times of challenging environmental and economic circumstances. The exploratory research discussed here examines possible responses for the Australian industry in terms of building innovations. The findings are likely to apply to most construction industries in developed countries because similar challenges are being confronted globally. Nevertheless, a limitation of this paper is its exploratory nature, which means that nothing can be said authoritatively about generalisablity. Future research is planned by the authors in order to examine the diffusion of the innovations in Chart 3, against the background of Rogers' Innovation-Decision process model (2003). That research is expected to contribute to theory by contextualising Rogers' model to take account of the peculiarities of the construction industry, compared to the manufacturing industry.

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